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# UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No. 61607-1280

First Named Inventor or Application Identifier William Lewis Betts

Title System And Method For Deriving Symbol Timing

Express Mail Label No. EL492174195US

## APPLICATION ELEMENTS

See MPEP Chapter 600 concerning utility patent application contents

## ADDRESS TO:

Assistant Commissioner for Patents  
Box Patent Application  
Washington, DC 20231

1.  Fee Transmittal Form (e.g., PTO/SB/17)  
(Submit an original, and a duplicate for fee processing)

2.  Specification [Total Pages 20]

- Descriptive title of the Invention
- Cross References to Related Applications
- Statement Regarding Fed sponsored R&D
- Reference to Microfiche Appendix
- Background of the Invention
- Brief Summary of the Invention
- Brief Description of the Drawings (if filed)
- Detailed Description
- Claim(s)
- Abstract of the Disclosure

3.  Drawing(s) (35 USC d113) [Total Sheets 4]

4. Oath or Declaration [Total Pages 2]

a.  Newly Executed (original or copy)

b.  Copy from a prior application (37 CFR §1.63(d))  
(for continuation/divisional with Box 17 completed)

[Note Box 5 below]

i.  DELETION OF INVENTOR(S)  
Signed statement attached deleting inventor(s)  
named in the prior application,  
see 37 CFR §1.63(d)(2) and 1.33(b).

5.  Incorporation By Reference (useable if Box 4b is checked)  
The entire disclosure of the prior application, from which a copy of  
the oath or declaration is supplied under Box 4b, is considered as  
being part of the disclosure of the accompanying application and is  
hereby incorporated by reference therein.

6.  Microfiche Computer Program (Appendix)

7.  Nucleotide and/or Amino Acid Sequence Submission  
(if applicable, all necessary)

a.  Computer Readable Copy

b.  Paper Copy (identical to computer copy)

c.  Statement verifying identical of above copies

## ACCOMPANYING APPLICATION PARTS

8.  Assignment Papers (cover sheet & Documents(s))

9.  37 CFR §3 73(b) Statement (when there is an assignee)  Power of Attorney

10.  English Translation Document (if applicable)

11.  Information Disclosure Statement (IDS)/PTO-1449  Copies of IDS Citations

12.  Preliminary Amendment

13.  Return Receipt Postcard (MPEP 503)  
(Should be specifically itemized)

14.  Small Entity Statement(s)  Statement filed in prior application  
(PTO/SB/09-12) Status still proper and desired

15.  Certified Copy of Priority Document(s)  
if foreign priority is claimed

16.  Other

\* A new statement is required to be entitled to pay small entity fees, except  
where one has been filed in a prior application and is being relied upon

17. If a CONTINUING APPLICATION, check appropriate box and supply the requisite information below and in a preliminary amendment:

 Continuation  Divisional  Continuation-in-part (CIP)

of prior application No. /

Prior application information: Examiner \_\_\_\_\_ Group / Art Unit: \_\_\_\_\_

## 18. CORRESPONDENCE ADDRESS



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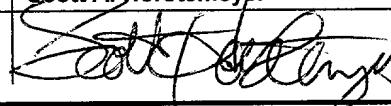
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PATENTS

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re: William Lewis Betts and Rafael martinez

Examiner: To Be Assigned

Serial No.: To Be Assigned

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Filing Date: Herewith

For: System And Method For Deriving Symbol Timing

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09/660346  
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Utility Patent Application Transmittal Page

Fee Transmittal Page

U.S. Utility Patent Application Consisting Of:

12 Pages of Specification

7 Pages of Claims

1 Page of Abstract

4 Pages of Formal Drawings

Declaration and Power of Attorney

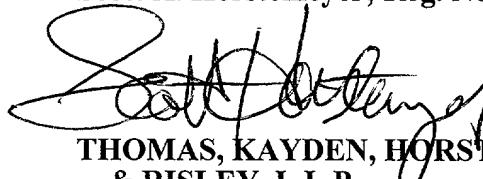
Assignment and Recordation Form Cover Sheet

Authorization to Charge Paradyne Deposit Acct. 16-0255

Further, the Commissioner is authorized to charge Deposit Account No. 16-0255 for any additional fees required. The Commissioner is requested to credit any excess fee paid to Deposit Account No. 16-0255.

Respectfully submitted,

Scott A. Horstemeyer; Reg. No. 34,183



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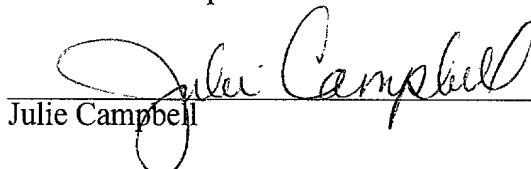
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The envelope has been given U.S. Postal Service "Express Mail Post Office To Addressee" Package # EL492174195US.

Date: September 12, 2000

Julie Campbell



## SYSTEM AND METHOD FOR DERIVING SYMBOL TIMING

### CROSS REFERENCE TO RELATED APPLICATIONS

This application claims priority to and the benefit of co-pending U.S. provisional  
5 patent application entitled, "Equalizer Derived Symbol Timing," filed on October 27,  
1999 and accorded serial number 60/161,799 (Docket No. 61606-8220; 1999-12), which  
is entirely incorporated herein by reference.

### TECHNICAL FIELD OF THE INVENTION

10 The present invention generally relates to modem communications, and more  
particularly to a system and method for deriving symbol timing in modems.

### BACKGROUND OF THE INVENTION

In recent years there has been an exponential expansion in the Internet and in the  
15 number of people who want to connect to the Internet. Businesses have found the  
Internet a cheap and efficient way of communicating information to their customers, to  
their suppliers, and even among their own workforce. Employees exposed to the Internet  
at work have gone in search of tools to connect the personal computers they have at home  
to the Internet so that they can have access to the vast resources they have become  
20 accustomed to at work.

The modem has filled this need for the past twenty years, but in the past ten years  
it has seen unprecedeted advances in technology. With the advent of the World Wide  
Web associated with the Internet, engineers have consistently needed to push larger and  
larger amounts of data through a pipeline that has not really grown. In the past few years,

with demand growing for “real-time” networks, designers have started to develop alternatives to the traditional modem after deciding that traditional modems most likely had a top speed around 56Kbps. These include digital subscriber line (DSL) modems, integrated services digital network (ISDN), and cable modems.

5        DSL modems in particular have received a lot of attention recently. DSL modems operate at higher data rates through a combination of higher frequency transmission and by using mapping techniques to map a series of bits onto a single symbol. These techniques typically require that both the transmitter and receiver are in sync with each other. When the systems are not in sync, either or both of the receivers are looking at an 10      incorrect portion of the signal. In such a situation, the systems are likely to see an incorrect phase angle or an incorrect magnitude, and the data ends up being misinterpreted.

15      In the past, synchronization has been done either through the use of a preamble, the use of an off frequency pilot tone or analysis of band edge signals. Using the preamble method, a known set of data is transmitted at the beginning of each transmission, and the receiver looks for this set of data and determines the characteristics of the transmission. The pilot tone method on the other hand, transmits a constant pattern of data (pilot tone) offset from the carrier frequency, thus allowing the receiver to derive the timing information from the pilot tone even in the absence of modulated data. The 20      band edge method filters the signal at each edge of the modulated bandwidth then performs non-linear operations to measure the bandwidth or symbol rate. Each of these systems has certain disadvantages.

## SUMMARY OF THE INVENTION

The present invention involves an improvement to a receiver of a modem in a half-duplex multi-point or point-to-point system or full duplex system that enables elimination of both the pilot tone and the preamble by deriving the symbol timing directly from the equalized or demodulated symbols. By employing the present invention, 5 modems are able to derive the incoming symbol timing from the received symbols. By deriving the symbol timing dynamically, the modem will conserve power over the pilot tone and make special start up preamble signals unnecessary, thereby reducing the time required to communicate data.

10 When the symbol timing derivation system is used in a multiple virtual lines (MVL) system, as an example, the invention uses a forward equalizer to clean up the signal, then the frequency is locked and the phase corrector rotates the constellation to the correct orientation for the slicer. The discrete data symbol produced by the slicer, which may include advanced data recovery techniques, is then rotated back into its original 15 orientation and subtracted from the pre-sliced signal and sent back to the forward equalizer to update the equalizer coefficients.

However, the invention can also be applied to, as another example, discrete multi-tone (DMT) systems, by using the received symbols to derive symbol timing. Here the symbol timing derivation system is very similar, but does not include a decision feedback 20 equalizer or a centroid error calculation, and replaces the non-linear decoder with a discrete Fourier transform (DFT) and a switch to handle the numerous carriers present in DMT.

The receiver includes a voltage controlled crystal oscillator (VCXO) which controls receiver timing and could allow the remote modems to transmit to the control

modem using a time base that is in sync with the received symbol timing. This reduces the need for timing correction or tracking in the equalizers at either end of the line.

The present invention can also be conceptualized as providing a method for communication in a modem. This method can be broadly summarized by the steps of:

- 5      decoding a received signal segment into a discrete data symbol, calculating a timing phase error and an average timing phase error based upon the received signal segment and discrete data symbol, creating a control signal based upon the average timing phase error, and generating symbol timing for a receiver based upon the control signal.

Other systems, methods, features, and advantages of the present invention will be  
10     or become apparent to one with skill in the art upon examination of the following drawings and detailed description. It is intended that all such additional systems, methods, features, and advantages be included within this description, be within the scope of the present invention, and be protected by the accompanying claims.

15

### **BRIEF DESCRIPTION OF THE DRAWINGS**

This invention can be better understood with reference to the following drawings. The components in the drawings are not necessarily to scale, emphasis instead being placed on clearly illustrating the principles of the present invention. Moreover, in the drawings, like reference numerals designate corresponding parts throughout the several  
20     views.

FIG. 1A is a block diagram of a first embodiment of the symbol timing derivation system of the present invention, which is situated in a DSL modem of a point to point system.

FIG. 1B is a schematic diagram of the first embodiment of FIG. 1A.

FIG. 2A is a block diagram of the second embodiment of the symbol timing derivation system of the present invention, which is situated in a multi-point system.

FIG. 2B is a schematic diagram of the second embodiment of FIG. 2A.

5

## **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT**

FIG. 1A shows a schematic view illustrating a point-to-point communications system 11 in which modems 13, 15, employing the concepts and features of a symbol timing derivation system, are used. Remote computer 14 and its DSL modem 13 is connected to a central office (CO) 16 via communications channel 12. Located at a central office 16, is DSL modem 15. The channel 12 can be a wire or wireless link, but is typically, although not necessarily, the copper wire pair that extends between a telephone company central office and a remote residential business, or any other location served by local telephone service. Remote computer 14 can be located at a residence, business, or any other location served by conventional copper wire pair where DSL modems 13, 15 may currently be used. By using modem 15 and modem 13 employing the concepts and features of the symbol timing derivation system 17, it is possible to derive symbol timing without the use of a symbol preamble or pilot tone. This feature allows both modems 13, 15 to maintain synchronization with each other, and advantageously conserve energy while maximizing data rate.

Now referring to FIG. 1B, shown is a schematic view illustrating the symbol timing derivation system 17 belonging to DSL modem 13 and/or DSL modem 15 of FIG. 1A including the concepts of the present invention. The transmitter 18 of modem 15 first

transmits a signal across the channel 12, which is modeled here by the addition of a phase rotation 22,  $\varphi$ , and additive noise 23,  $n$ , from the line, to the receiver 19 of a remote modem 13. This embodiment of the symbol timing derivation system 17 begins with the forward equalizer 24. The forward equalizer 24 takes the incoming signal and uses its coefficients to clean up the signal by removing intersymbol interference and reducing signal noise.

Once the forward equalizer 24 has adjusted the signal, the symbol timing derivation system 17 allows for a non-linear decoder 25, the use of which is described in US Patent number 5,265,127 to Betts, *et al.* which is hereby incorporated by reference.

10 The non-linear decoder 25, however, is not included in the preferred embodiment. When operating in a discrete multi-tone (DMT) system, which is well known in the art, this non-linear decoder block 25 would be replaced by a Discrete Fourier Transform (DFT) producing numerous outputs in the frequency domain. These numerous outputs correspond to the different multi-tone carrier frequencies of the received signal. A switch 15 controls which carrier is fed into the symbol timing derivation system 17 at any instant in time.

In the next step, the results of the decision feedback equalizer 33 are subtracted 26 from the incoming signal. This step allows the receiver to subtract 26 from the signal any past signals that may have seen time dispersion as a result of the channel. The resulting 20 signal, eq\_xeye 27, is then fed to three different components.

The first component to be discussed will be the slicer 29. The signal, eq\_xeye 27, is first phase rotated by  $-\varphi$  28. This phase rotation 28 puts the constellation in the correct (squared up) orientation for the slicer 29, so that the slicer 29 does not

misinterpret the signal as being in an incorrect decision region due to phase error. The slicer 29 then decides where the constellation point lies. Additionally, any advanced data recovery techniques, such as well known trellis coding, may be applied in the slicer 29.

The slicer 29 then produces a reference signal 30 in the form of a discrete data symbol,

- 5 which locates the constellation point at the center of a decision region. It should be appreciated that the above description of a slicer 29 should not limit the symbol timing derivation system 17 to operate only on quadrature amplitude modulated systems. The slicer 29 should be interpreted as a decision function in any modulation technique to decide where a signal should be interpreted to be located, including any amplitude shift
- 10 keying, phase shift keying, or frequency shift keying techniques, or any combination thereof. The reference signal 30 is then phase rotated 31 back to its original orientation. The resultant signal 32 then updates the decision feedback equalizer (DFE) 33 and the phase corrector 36, although when operating in DMT, the symbol timing derivation system 17 could operate without a DFE 33. Even in DMT though, the symbol timing derivation system 17 can benefit from the inclusion of a noise whitening DFE 33 to further refine the signal.

The inputs to the DFE 33 include the sliced signal  $(X'_r, Y'_r)$  32, minus the unsliced signal 27, which indicates the error present in the DFE compensated signal, and the sliced signal 32 minus the result of the forward equalizer 24 delayed by one cycle,

- 20 which shows both channel dispersion and signal noise. The result of the sliced signal 32 minus the unsliced signal 27 also results in the update error 34, which is sent to the forward equalizer 24 to update its coefficients. With respect to the second input to the DFE 33, one skilled in the art will recognize that this subtraction 35 can also occur after

the delay, with the caveat that the corresponding signal 32 needs to be properly synchronized. The DFE 33 in this embodiment is a noise whitening DFE 33, and decides what part of the signal is due to noise 23 from the channel 12 and subtracts 26 the noise 23 from the output of the forward equalizer 24.

5        The use of a phase corrector 36 is known in the art. An example of a phase corrector can be seen in U.S. Patent number 4,532,640 to Betts *et al.*, which is hereby incorporated by reference. The inputs to the phase corrector 36 consist of eq\_xeye 27 and  $(X'_r, Y'_r)$  32. The phase corrector 36 multiplies the signals 27, 32 together and multiplies the result by  $2^4$ , a scalar. The phase corrector 36 then combines the product to  
10      the previous result (e.g., integrates), sending the result 37,  $\varphi'$ , to phase rotator 31 also to an inverter 38, which inverts the result 37 and sends it to phase rotator 28.

Finally, the eq\_xeye signal 27 is used to derive the timing phase error. The equation for deriving the timing phase error is as follows:

$$t_e = y_e \cdot x_r - x_e \cdot y_r$$

15      where the result is the product of the constellation vector 27 and the reference vector 30. This result shows how much the eq\_xeye 27 signal has rotated in relation to the ideal reference vector 30. As is known in the art, the circuit may use the phase rotated vector  $(X'_r, Y'_r)$  32, to derive the timing phase error, the difference is that the phase corrector in such a circuit will be a 360 degree phase corrector. In contrast, the present embodiment  
20      utilizes a phase corrector 36 that can correct up to one radian of error. Back to the present embodiment the timing error resulting from multiplier 39 is then multiplied by a scalar 40,  $2^4$  in this embodiment, and is input to a leaky integrator 41 which calculates the

average timing phase error. The other input to the leaky integrator 41 is communicated from the centroid error 48 which is combined via adder 42 to the scaled timing phase error and integrated 41. It should be added that in DMT, there should be no centroid error calculation unless the DMT equalizer adaptively updates its coefficients.

5 Calculation of the centroid error 48 begins with the calculation of the centroid 44 itself. The centroid 44 is calculated according to the following equation:

$$\text{Centroid} = \frac{\sum i \cdot |C_i|}{N}$$

Where  $i$  is the equalizer coefficient index,  $C_i$  is the coefficient, and  $N$  is the total number of coefficients. The error is then calculated by sending the result of the centroid block 44

10 to a subtractor block 45, which subtracts the ideal signal 46 from the centroid. The centroid 44 may be the true centroid or the location of the largest magnitude equalizer coefficient. For a 36-coefficient equalizer, the ideal centroid 46 has been set at 19, which biases the equalizer to the high side of halfway. The subtraction result is then sent to a multiplication block 47, where it is multiplied by a scalar,  $\beta_C$ . In ideal conditions, the 15 centroid error 48 will be zero. However, when the centroid error 48 becomes non-zero, the centroid error 48 biases the leaky integrator, and thus the VCXO 57, to compensate for the movement of the equalizer coefficients so that the coefficients will move back to the center, or ideal position. Without the centroid calculation 44, the equalizer 24 coefficients can make a random walk to either extreme, at which point the equalizer 20 can no longer correct for additional error in the signal.

The summation 42 result is then input to a subtractor 43 along with a scaled 50 version of the previous result delayed one cycle by the delay block 49. The result of the leaky integration 41 is as follows:

$$\varphi e_n = \left(1 - 2^{-4}\right) \varphi e_{n-1} + e_c + 2^{+4} t_e$$

5 where  $\varphi e_n$  is the timing phase error,  $\varphi e_{n-1}$  is the previous timing phase error,  $e_c$  is the centroid error 48, and  $t_e$  is the timing error computed above.

The final portion of the symbol timing derivation system to be discussed is the voltage controlled crystal oscillator (VCXO) 57 control circuit 51. This circuit 51 is comprised of a second order phase locked loop (PLL) 51 which develops the control 10 voltage for the VCXO 57. The output of the leaky integrator 41 described above is split and fed into two different multipliers 52, 53. The first multiplier 52 multiplies the signal by the scalar  $2^{-2}$ , while the second multiplier 53 multiplies the signal by  $2^{-16}$ . The output of this second multiplier 53 is then fed to an ideal integrator, which is made up of a summation block 54 and a delay element 55. The output of the ideal integrator 54 is taken 15 at the output of the delay element 55 and fed to a summation block 56, where it is added to the result of the first multiplier 52 to control the VCXO 57. The resulting equations are as follows:

$$VCXO = 2^{-2} \varphi e_n + \Delta f$$

and

$$\Delta f = \Delta f + 2^{-16} \varphi e$$

20 where  $\varphi e$  is the timing phase error, and  $\Delta f$  is the second order frequency offset.

In an alternative embodiment shown in FIG. 2A, the symbol timing derivation system 66 is used in a multi-point system 60. FIG. 2A shows a central office DSL modem 61 with a transmitter 65 and a receiver 64, which contains the symbol timing derivation system 66, connected to many remote DSL modems 63, also equipped with a transmitter 65 and receiver 64, and containing the symbol timing derivation system 66. The symbol timing derivation systems 66 of these DSL modems 61, 63 are shown in FIG. 2B. The novelty here is the dual eye closure 71, 72. The eye closure functions 71, 72 sense when no signal is present and opens the flywheel switch 73. Prior to the present embodiment 66, DSL modems only included one eye closure 71. What prior embodiments did not consider, however, is that even when no signal is present, the DFE 33 might create a signal, thus eye close 71 might not realize that no signal is present. Therefore, a second eye close 72 was added to detect when no signal was present coming out of the forward equalizer 24. Eye close 71 is still used, though, because it takes advantage of both the DFE 33 for noise reduction, and the phase corrector 36, to rotate the signal back to the correct orientation. The eye closures 71, 72 may be used in point-to-point systems 11 running in full duplex, to correct for carrier dropout, but is normally used when running half duplex in either point-to-point 11 or multi-point systems 60 (e.g., a multiple virtual lines (MVL) system, as is described in U.S. Patent No. 6,061,392 to Bremer *et al.*, which is incorporated herein by reference).

The symbol timing derivation systems 17, 66 described above can be implemented in software, hardware, or a combination thereof. In the preferred embodiment, the elements of the symbol timing derivation systems 17, 66 are implemented in software that is stored in a memory and that configures and drives a

suitable digital signal processor (DSP), a variety of which are well known in the art, situated in a modem. However, the foregoing software can be stored on any computer-readable medium for transport or for use by or in connection with any suitable computer-related system or method. In the context of this document, a computer-readable medium 5 is an electronic, magnetic, optical, or other physical device or means that can contain or store a computer program for use by or in connection with a computer-related system or method.

It should be emphasized that the above-described embodiments of the present invention, particularly, any “preferred” embodiments, are merely possible examples of 10 implementations, merely set forth for a clear understanding of the principles of the invention. Many variations and modifications may be made to the above-described embodiments of the invention without departing substantially from the spirit and principles of the invention. All such modifications and variations are intended to be included herein within the scope of this disclosure and the present invention and 15 protected by the following claims.

## CLAIMS

Therefore, having thus described the invention, at least the following is claimed:

1. A system to derive symbol timing for a receiver, comprising:
  2. a slicer that decodes a received signal segment into a discrete data symbol;
  3. a calculator that receives the received signal segment and the discrete data symbol, that derives a timing phase error based upon the received signal segment and discrete data symbol, and computes an average based upon said timing phase error;
  4. a circuit that receives the average and that develops a control signal based upon the average; and
  5. an oscillator that receives the control signal and that generates symbol timing for a receiver.
1. 2. The system of claim 1, wherein the calculator comprises a multiplier and a leaky integrator.
1. 3. The system of claim 1, wherein the slicer employs an advanced data recovery technique for decoding the received signal segment.
1. 4. The system of claim 1, wherein the circuit comprises a phase locked loop.
1. 5. The system of claim 1, wherein the oscillator is a voltage controlled oscillator.

1           6.       The system of claim 1, wherein the oscillator is configured to generate  
2       symbol timing for a transmitter.

1           7.       The system of claim 1, wherein the system is part of a point-to-point  
2       system.

1           8.       The system of claim 7, wherein the system is part of a full duplex system.

1           9.       The system of claim 7, wherein the system is part of a half duplex system.

1           10.      The system of claim 1, wherein the system is part of a multi-point system.

1           11.      The system of claim 10, wherein the multi-point system operates on  
2       discrete multi-tone protocol.

1           12.      The system of claim 10, wherein the multi-point system operates on  
2       carrier amplitude modulation protocol.

1           13.      The system of claim 10, wherein the multi-point system operates on  
2       multiple virtual lines protocol.

1           14.      The system of claim 13, further comprising a fractionally spaced forward  
2       equalizer producing a plurality of coefficients.

1 15. The system of claim 14, further comprising a centroid error calculation for  
2 the plurality of coefficients received from the fractionally spaced forward equalizer.

1                   16.       The system of claim 15, wherein the calculator is configured to subtract  
2       the centroid error calculation from the average.

1        17. The system of claim 13, further comprising a dual eye close structure, the  
2        first eye close being coupled to the received signal segment and the second eye close  
3        being coupled to an output of a decision feedback equalizer, wherein said first and second  
4        eye closes control a switch to remove the signal path from the calculator to the circuit.

1           18.    A system to track symbol timing for a receiver, comprising:

2                    a forward equalizer for receiving a signal segment and for producing an

3                    equalized signal based upon a plurality of coefficients applied to the received signal

4                    segment;

5                    a centroid error calculator for receiving a plurality of coefficients from the

6                    forward equalizer and for calculating a centroid error from the plurality of coefficients

7                    and a nominal number based upon the plurality of coefficients;

8                    a first subtractor for receiving the equalized signal from the forward

9                    equalizer and a noise correction calculated by a decision feedback equalizer, and for

10                  calculating a first difference based upon the equalized signal and the noise correction;

11                  a first phase rotator for receiving the first difference from the first

12                  subtractor and an inverted result of a phase corrector, and for producing a square signal

13                  based upon the first difference and the inverted result;

14                  a slicer or receiving the square signal from the first phase rotator, that

15                  decodes the square signal into a discrete data symbol;

16                  a first multiplier for receiving the first difference and the discrete data

17                  symbol, and for deriving a timing phase error therefrom;

18                  a leaky integrator for receiving the timing phase error and the centroid

19                  error calculation and for producing an average timing phase error based upon the timing

20                  phase error and the centroid error calculation;

21                  a switch for receiving the average timing phase error and an eye close

22                  signal from a first and second eye close function, which opens a connection to a phase

23       locked loop when the eye close signal is asserted, the eye close signal being asserted by  
24       the first or second eye close functions when no received signal segment is sensed;  
25                    a phase locked loop for receiving the average timing phase error when the  
26       switch is closed and producing a control voltage; and  
27                    a voltage controlled oscillator for receiving the control voltage from the  
28       phase locked loop and generating symbol timing for a receiver.

1           19.      A system to track symbol timing for a receiver, comprising:  
2                    means for decoding a received signal segment into a discrete data symbol;  
3                    means for calculating a timing phase error, based upon the received signal  
4       segment and discrete data symbol, and an average timing phase error;  
5                    means for creating a control signal based upon the average timing phase  
6       error; and  
7                    means for receiving the control signal and generating symbol timing for a  
8       receiver.

1           20. The system of claim 19, wherein the system further comprises:  
2                   means for equalizing the received signal;  
3                   means for computing a centroid error based upon coefficients of the  
4                   equalizing means;  
5                   means for subtracting the centroid error from the average timing phase  
6                   error; and  
7                   means for opening the circuit between said calculating means and said  
8                   means for creating the control signal.

1           21. A method for deriving symbol timing, comprising the steps of:  
2                   decoding a received signal segment into an discrete data symbol;  
3                   calculating a timing phase error and an average timing phase error based  
4                   upon the received signal segment and discrete data symbol;  
5                   creating a control signal based upon the average timing phase error; and  
6                   generating symbol timing for a receiver based upon the control signal.

1           22. The method of claim 21, further comprising the step of generating symbol  
2                   timing for a transmitter based upon the control signal.

1           23. The method of claim 21, further comprising the steps of:  
2           equalizing the received signal with a forward equalizer;  
3           calculating the centroid of the coefficients of the forward equalizer; and  
4           subtracting the centroid of the coefficients of the forward equalizer from  
5           the average.

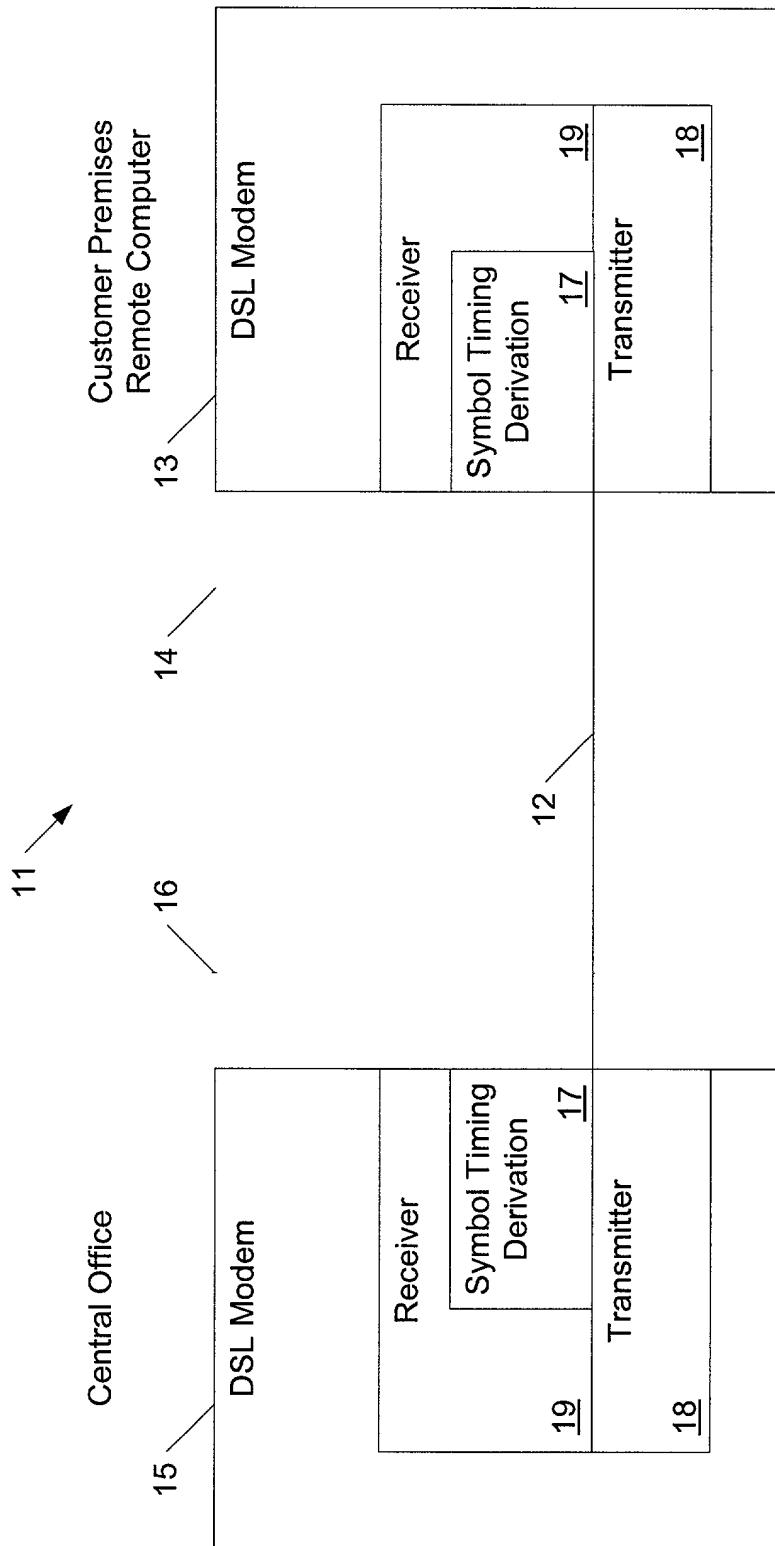
1           24. The method of claim 21, further comprising the steps of:  
2           using a first eye close test on the received signal;  
3           cleaning noise from the received signal with a decision feedback  
4           equalizer;  
5           using a phase corrector to put a constellation in a correct orientation;  
6           using a second eye close test on the constellation; and  
7           opening a flywheel switch when an output of the first or second eye close  
8           is asserted.

## ABSTRACT OF THE DISCLOSURE

A symbol timing derivation system derives receiver timing from received symbols which avoids the need for a pilot tone, thereby reducing power consumption and expanding usable bandwidth. The system is implemented by using a calculation that

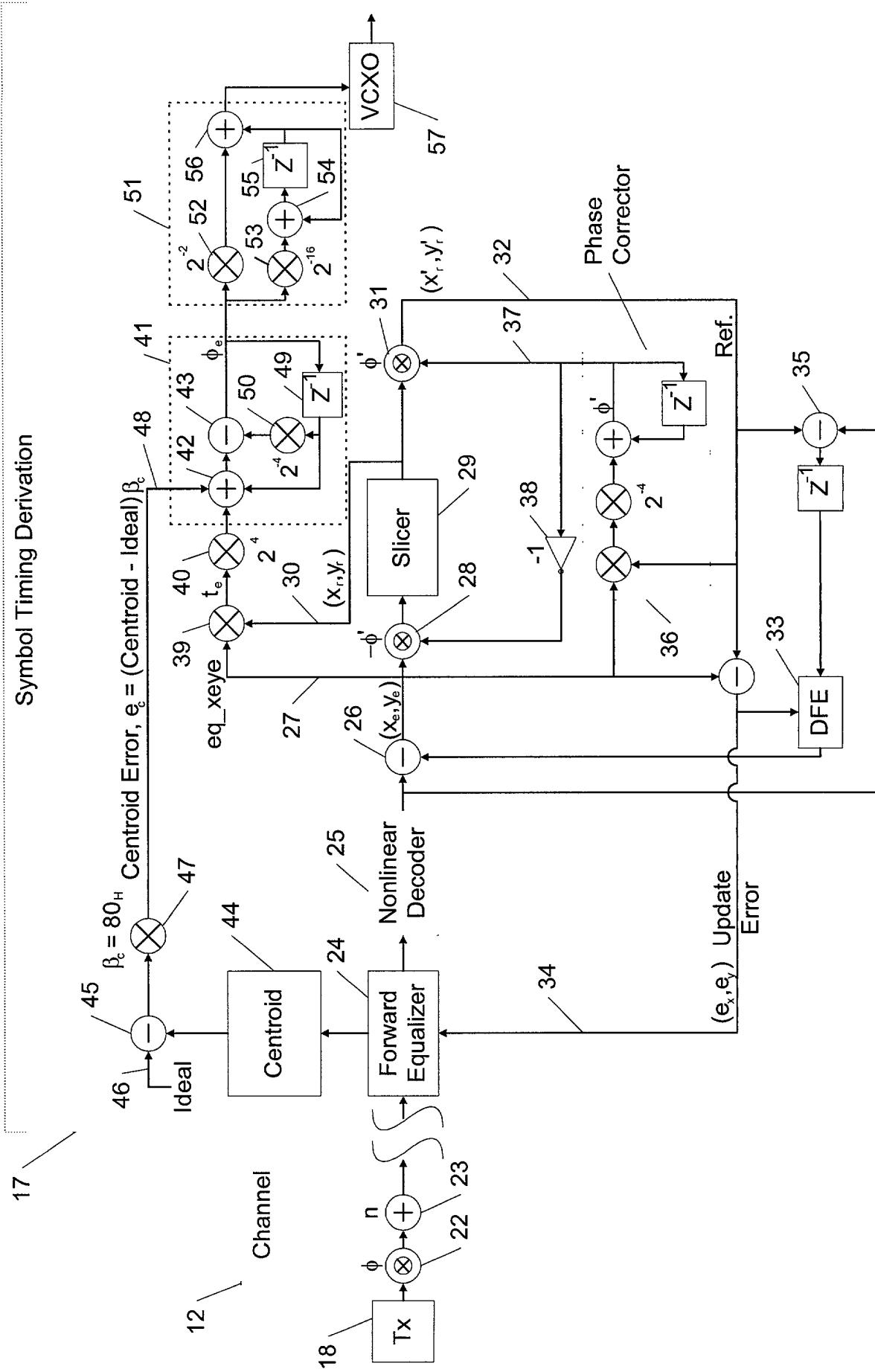
5 finds the timing phase error. The timing phase error is then averaged and controls a phase locked loop (PLL). This PLL in turn controls a voltage-controlled oscillator, which handles the modem receiver timing. A centroid calculation can be included to bias the voltage-controlled oscillator to push the equalizer coefficients back to the ideal position. The system can be implemented in either a point-to-point modem environment

10 or a multi-point environment, for example, but not limited to, MVL or DMT. The voltage-controlled oscillator may also be implemented to control transmitter timing, so that the central office modem and the remote modem will operate more-or-less synchronously, reducing the need for large equalizer corrections at either end.

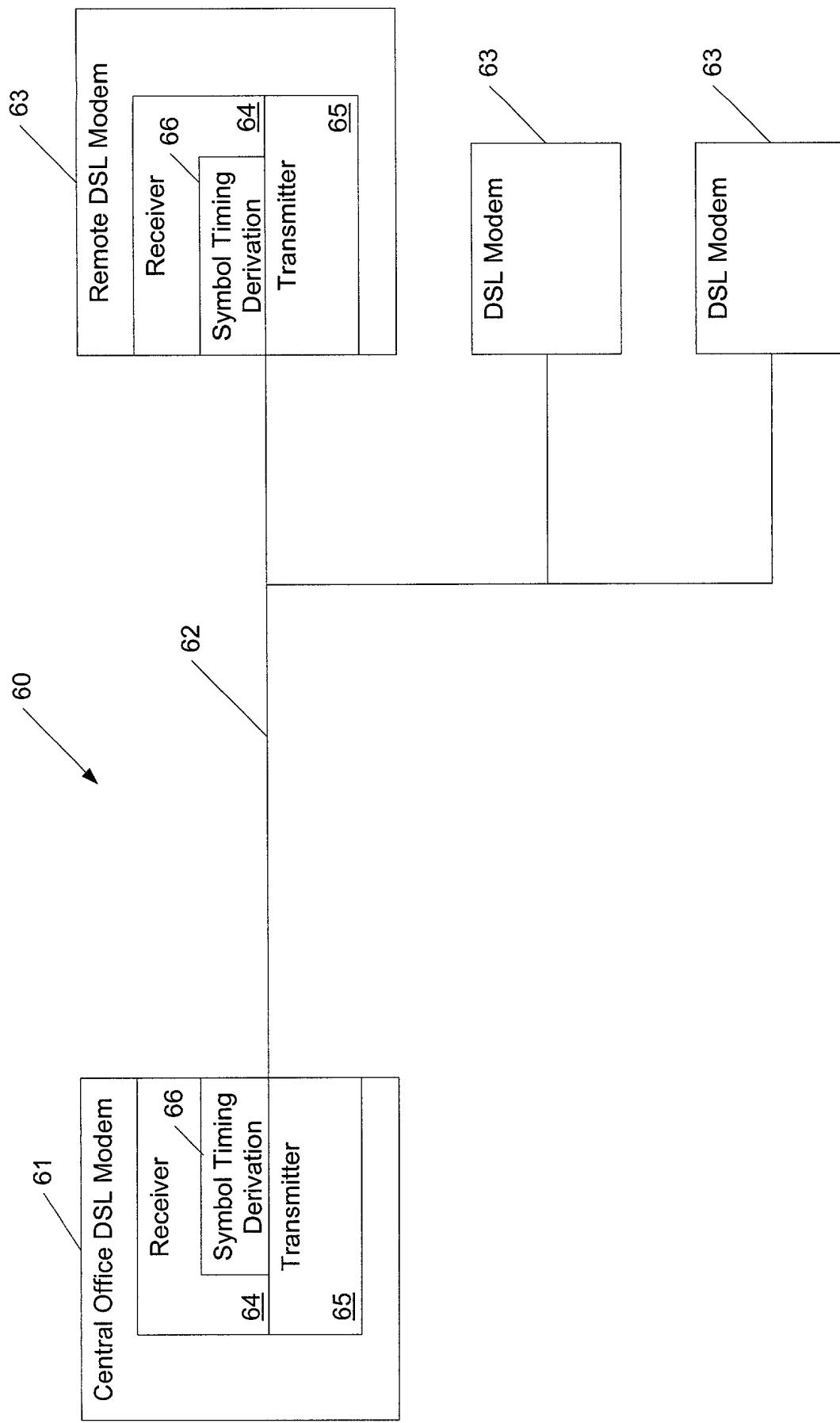


**FIG 1A**

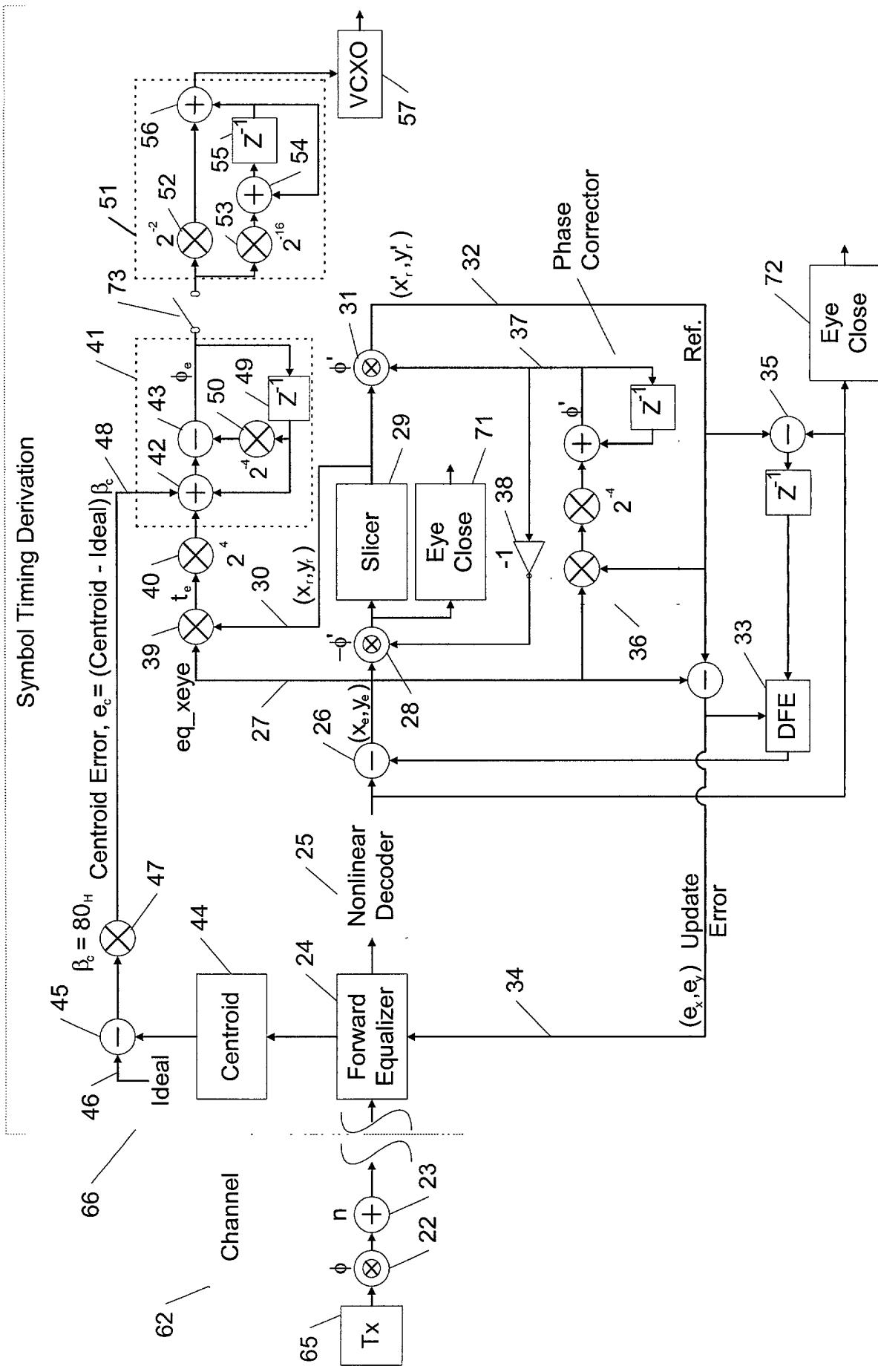
FIG 1B



# FIG 2A



## FIG 2B



## DECLARATION FOR PATENT APPLICATION

Attorney Docket No: **61607-1280**

As the below named inventor, I hereby declare that:

Our residences, post office addresses and citizenships are as stated below next to our names.

We believe we are the original, first, and joint inventors of the subject matter which is claimed and for which a patent is sought on the invention entitled **System And Method For Deriving Symbol Timing**, the specification of which:

is attached hereto.  
 was filed on \_\_\_\_\_ as Application Serial No. \_\_\_\_\_.  
 was filed on \_\_\_\_\_ under U.S. Express Mail No. \_\_\_\_\_.  
 is set forth in PCT International Application No. \_\_\_\_\_;  
filed on \_\_\_\_\_ and as amended Under PCT Article 19 on \_\_\_\_\_ (if any).

I/we hereby state that I/we have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I/we acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56.

I/we hereby claim the benefit under Title 35, United States Code, §119 of any United States provisional patent application, foreign application(s) for patent or inventor's certificate listed below and have also identified below any United States provisional patent application, foreign application for patent or inventor's certificate having a filing date before that of the above-identified application on which priority is claimed: **Provisional Patent Application Ser. No. 60/161,799; filed 10/27/99, entitled "Equalizer Derived Symbol Timing"**

I/we hereby claim the benefit under Title 35, United States Code, §120 of any United States patent application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I/we acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56 which occurred between the filing date of the prior application and the national or PCT international filing date of this application: **NOT APPLICABLE**.

I/we hereby appoint the following attorneys/agents to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith: **George M. Thomas, Reg. No. 22,260; James W. Kayden, Reg. No. 31,532; Scott A. Horstemeyer, Reg. No. 34,183; Stephen R. Risley, Reg. No. 35,659; Jeffrey R. Kuester, Reg. No. 34,367; Daniel J. Santos, Reg. No. 40,158; Michael J. Tempel, Reg. No. 41,344; Daniel R. McClure, Reg. No. 38,962; Robert E. Stachler II, Reg. No. 36,934; David P. Kelley, Reg. No. 17,420; Reg. No. 41,344; David R. Risley, Reg. No. 39,345; Jon E. Holland, Reg. No. 41,077; Dan R. Gresham, Reg. No 41,805; J. Scott Culpepper, Reg. No. 41,692; M. Paul Qualey, Reg. No 43,024; Robert P. Biddle, Reg. No. 35,826; Robert A. Blaha, Reg. No. 43,502; Jennifer M. Gruber, Reg. No. 42,601; Raymond W. Armentrout, Reg. No. 45,866; Cynthia J. Lee, Reg. No. 46,033; N. Andrew Crain, Reg. No. 45,442; Monica A. Hyson, Reg. No. P46,790; Sami O. Malas, Reg. No. 44,893; Marianne H. Parker, Reg. No. 46,169; Eric M. Ringer, Reg. No. P47,028**

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statement and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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Residence: \_\_\_\_\_ Citizenship: \_\_\_\_\_  
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